NATURAL HISTORY OBSERVATIONS OF THE FOUR-HORNED ANTELOPE *TETRACERUS QUADRICORNIS*

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The Four-horned Antelope is endemic to the Indian subcontinent and is defined as data deficient by IUCN. It is found mainly in forest habitats and is usually solitary. A four-year long study was conducted on the species in Panna National Park, Madhya Pradesh, during which behavioural observations were made using opportunistic focal sampling, mapping and monitoring middens, and cafeteria experiments. A total of 2,902 minutes of cumulative observations of the Four-horned Antelope were made in the field, including 352 events when anti-predatory behaviour was recorded. It was found that the species had a preference for browsing over grazing. It was found using closed canopy thickets, with dense undergrowth or grass cover, for resting unlike Chinkara, which is a sympatric antelope of the same size. The behavioural observations were restricted to the more obvious behaviours, but provided us with a good opportunity to document these for the first time. These include mating, inter and intra-specific interactions, and anti-predatory behaviour. Data on midden locations and their usage over time were also collected to understand the stimulus behind defecation by adults and young ones on middens. It was found that while the Four-horned antelope has a peculiar anti-predatory behaviour where it prefers to hide than run, making it conspicuous and this possibly affected its choice of habitat. The middens were found to be randomly placed in space and their usage pattern indicated that they were used as points of communication between conspecifics of different age and sex groups.

Key words: Four-horned antelope, behaviour, Panna National Park, tropical dry deciduous forest, middens, anti-predatory behaviour

INTRODUCTION

Studying the behaviour of animals in the wild provides useful inputs for their management (Leuthold 1977; Kilgo *et al.* 1998). The pattern of usage of habitats by animals differs greatly with activity. For many species of animals, the behaviour changes to a great extent with different levels of anthropogenic pressure (Kilgo *et al.* 1998; Bolhuis and Giraldeau 2005; Rabin 2003). While almost all census methodologies rely on some basic understanding of animal behaviour, the reaction of animals to environmental conditions, degree of adaptability to different circumstances, and conflict with humans can be best understood by gaining an in-depth knowledge of their behaviour. Behavioural traits of living species provide useful information about their evolution (Janis 1981, 1990), and about other closely related or sympatric species that have gone extinct. Behavioural ecology also provides an insight into a species' relationship with other ecological and evolutionary features, such as morphology, grouping tendencies and niche occupancy.

The Four-horned Antelope *Tetracerus quadricornis* is endemic to the Indian subcontinent, being found only in India and a few pockets of Nepal. Due to its preference for forested and undulating terrain (Prater 1980) and solitary living, it is considered one of the most elusive antelopes in India. It was considered data deficient by IUCN (Rahmani 2001) as there was little information available about its behaviour and ecology other than some observations made by Berwick (1974) in Gir, and by Bhaskaran (1999) and Kannan (1999) in Mudumalai. Apart from these studies, there were only a few historic records that discuss the distribution and behaviour of the Four-horned Antelope in greater detail (Jerdon 1867; Blanford 1888-1891; Brander 1923; Prater 1980).

The Four-horned Antelope differs in behaviour and habitat preference from the other five antelope species found in India. It is found predominantly in forest habitats, whereas the Nilgai *Boselaphus tragocalemus* uses forested and open habitats alike. The Chinkara *Gazella bennettii* and Blackbuck *Antilope cervicapra* are restricted to open habitats (Schaller 1967; Ranjitsinh 1982; Rahmani 1990a,b; Rahmani and Sankaran 1991; Isvaran 2005; Alfred *et al.* 2001), while the Chiru *Pantholops hodgsonii* and Tibetan Gazelle *Procapra picticaudata* dwell in the Himalayan mountain ranges that are scantily vegetated (Prater 1980; Menon 2003). The Four-horned Antelope is usually solitary but can be seen occasionally in loosely associated groups of three to five animals. The other antelopes usually have larger mean group sizes, with the exception of the Chinkara, which is found in smaller groups. However, even the Chinkara can be seen in groups as large as 17 in summer (Rahmani 1990b).

Different species have developed different morphological traits to serve as secondary sexual characters. The Four-horned Antelope is unique in having two distinct pairs of horns. The other known living species to have four horns is the domesticated Four-horned Sheep found in Britain and a Four-horned Chamois described once (Beddard 1902). Some Pronghorn Antelopes (*Antilocapra americana*) develop a split in their horns near the root, giving it the appearance of having four distinct horns, but since its family is now segregated from the antelopes as the Family Antilocapridae, there is no other known species of antelope that regularly grows four distinct horns. It is important to study the behaviour of animals to understand the evolutionary stimuli behind the development of such unique characters. Morphological features help animals in attracting mating partners, but their development into those of super-prominence is often checked by the costs they have to pay for it. An insight into the mating and anti-predatory behaviour of the Four-horned Antelope is expected to provide clues about the factors behind the development of two sets of horns in this small antelope.

We classified behavioural observations into three major classes, namely foraging, reproducing and predation avoidance. These three broad behavioural classes covered most of the activities recorded in the field. The three aforementioned categories were studied with an objective of understanding the ecology of the Four-horned Antelope. Its foraging and anti-predatory behaviour provide an understanding about the pattern of habitat use. Using these observations, an attempt was made to explain the possible relationships between the various behavioural traits observed in the field and to link them to the ecological and evolutionary biology of the Four-horned Antelope. An attempt was also made to relate its behavioural ecology with the niche that it occupies in the forest ungulate community.

STUDY AREA

The Panna National Park is situated between the coordinates 24° 15'-24° 20' N and 80° 00'-80° 15' E towards the northern boundary of the state of Madhya Pradesh. It is 543 sq. km of Tropical Dry Deciduous Forest with an altitude ranging between 200 m and 550 m. Situated in the Vindhyan Hill Ranges, the terrain of Panna National Park is typified by extensive plateaux and gorges. It has a unique bench topography that discriminates the area into Hinauta (middle) and Talgaon (upper) plateaux respectively. The meandering Ken river splits the Park into valleys, steep slopes, cliffs, deep gorges and mud banks along the 54 km of its course through the Park. Along its course, the river goes beyond the Park boundaries for about 13 km from near Gangau village and re-enters near Kaneri village. The entire National Park acts as catchment to the Ken river and the area's major surface water flow is towards north and north-east. The Vindhyan sandstone provides a good medium to recharge aquifiers and at some places the water keeps trickling throughout the year from perennial springs.

METHODOLOGY

Opportunistic Focal Animal Sampling

Focal animal sampling (Altmann 1974) was used to study the behaviour of Four-horned Antelopes. However, systematic behavioural study using this method mandates prolonged observations of identified individuals. Four-horned Antelopes do not have any distinct morphological patterns (e.g. stripes, spots, unique horn/antler shapes) that may help identify individuals. Since no animals were radio-tagged during the study period, identification of individuals was difficult. All opportunistic sightings were considered as independent observations. The Four-horned Antelope lives solitarily or in very small groups. Random encounters of Four-horned Antelopes were sought, followed by specific efforts to get the animal accustomed to the observer's presence. Once located, individuals were observed as long as the observer was tolerated by the animal.

Between December 2002 and June 2005, Four-horned Antelopes were observed on 705 occasions (978 animals). Notes on their activities and behaviour were taken from 500 independent sightings in the field. Those animals that fled immediately after being detected were excluded from the analysis as it was difficult to judge their activity in the moments before they fled.

Between November 2002 and January 2003, a thorough survey of the study area was done, and areas with a high probability of sighting the Four-horned Antelope were identified. These sites were intensively surveyed thereon for locating and observing individuals. The Event Instances (frequency) and Event States (duration) of animals were recorded along with an additional variable denoting whether the animal was in a visibly disturbed or undisturbed state due to the presence of the observer. The Four-horned Antelope is shy and quite elusive in its escape tactics, and therefore an individual could be observed continuously for long durations (>10 minutes) on only a few occasions. The maximum duration for which an individual was observed was about 2.5 hours.

One of the constraints in this method of observing behaviour was in locating an individual, almost invariably the animal had to be in an active state when first seen. This bias was inevitable as the Four-horned Antelope prefers thick

undergrowth and grass with very low visibility for resting. The greatest number of behavioural observations could be obtained during 0600-1000 hrs and 1600-1900 hrs, presumably because it mostly rests during the hotter part of the day. However, occasional sightings were obtained at odd hours, for example at 1200 hrs, 1500 hrs and 2200 hrs.

Preliminary analysis suggested that the data obtained from the second and third years of study were different from those of the first year. Too many bouts of behaviour forced by the observer's presence (e.g. alert and alarmed positions) were obtained during the second year. This was possibly because the study team used a jeep during the first year and a motorcycle in the second. Covering the human figure in its silhouette, a jeep that does not make too much noise allowed a closer approach and longer observations of the animals. In contrast, motorcycles usually scared away the Four-horned Antelope inadvertently as these animals were usually shy and wary of conspicuous human figures.

Midden Mapping and Monitoring

The Four-horned Antelope, like many other ungulates (Leuthold 1977; Ranjitsinh 1982; Acharjyo *et al.* 1990; Biswas and Sankar 2002), has a tendency to defecate on middens. It was seen that many middens were shared not only by more than one individual, but also by different species. Nilgai, Chinkara and Four-horned Antelopes were often seen defecating on certain middens at different times of the day. A systematic approach was followed to understand the purpose of making and maintaining middens (Leuthold 1977; Black-Decima 2000). Middens were mapped and monitored over a period of 7 to 15 days. Faecal pellets can be used to provide evidence of the presence as well as abundance of an animal in an area (Neff 1968; Marques *et al.* 2001). Seven areas with a high encounter rate of Four-horned Antelopes were randomly chosen and demarcated. Thorough searches were done to locate and identify middens in these areas. A team of two to three observers walked along fixed paths, traversing a strip of width 5-10 m. On reaching the edge of the demarcated area, the adjacent strip was traversed when searching for middens. This exercise was repeated till the whole plot was searched. Physical barriers (cliffs, steep slopes, roads, etc.) were considered as boundaries for these demarcated plots when mapping them. The coordinates of each midden were noted with the help of a Global Positioning System (GPS), and it was classified on the basis of its size (Table 1). The status of the midden was estimated visually on the basis of pellet groups seen on it, and the species that seemed to have been defecating on it were identified. Once mapped, middens from a selected area were visited daily for five to seven days. The time of visit was chosen close to noon, on the assumption that most animals would be resting during the hotter periods of the day. Fresh defecations were identified and classified into the two categories of 'morning' and 'previous evening'. In addition, the species was identified and the number of pellets in a single defecation group counted. After noting information and collecting some fresh pellets, the fresh defecation was patted and pressed gently to flatten the heap. This was done to identify fresh defecations with certainty on the next day's visit. Since the stimulus for the antelope revisiting the midden was unknown, precautions were taken not to disturb the fresh pellet group's density and its position on the midden as this could have affected the next visit of the antelope. It was possible to distinguish pellets defecated by different individuals on a midden within a day's span as in most instances there were some diagnostic differences in shape, size, colour and placement of the defecation on the midden.

Table 1: Midden classes (based on midden diameter)

Classification	Criteria
Order 1	<50 cm
Order 2	50 cm to 1 m
Order 3	1 m to 2 m
Order 4	>2 m

Cafeteria Experiment

To investigate food preferences, cafeteria experiments were conducted on a captive Four-horned Antelope in Van Vihar National Park cum Zoo in Bhopal, Madhya Pradesh. The enclosure was about 275 sq. m in area, with Common Grass *Cynodon dactylon* and a Babool *Acacia nilotica* tree within it being the source of food. A single male Four-horned Antelope, about 18 months old, had been held captive for about 7 months. Five sessions of the cafeteria experiment were conducted in the enclosure in the last week of October 2002. These sessions were of 2 hours duration and would start early in the morning at about 0730 hrs and last till about 0930 hrs and start again at 1330 and continue till 1530 hrs.

Ten species of vegetation were provided to the animal, spread out in front of it in a semi-circular fashion so that it had equal access to all species. The species provided to the Four-horned Antelope were Ber *Ziziphus mauritiana*, Khair *Acacia cateclu*, Aonla *Emblica officinalis*, Renjha *Acacia leucophloea*, Babool *Acacia nilotica*, Amaltas *Cassia fistula* and the following grasses: Bamboo *Dendrocalamus strictus*, Lampa *Heteropogon contortus*, *Themeda triandra* and *Cynodon dactylon*.

RESULTS

A total of 2,902 minutes (approximately 48 hours) of cumulative observation of the Four-horned Antelopes in the field was performed. Data were broadly classified into two categories, namely forced and natural behaviour. Forced behavioural bouts were those that were influenced by the presence of the observer. These were generally discarded for most analyses but were used for describing the threat response of the animal.

The natural behaviour observations were classified into Event States and Event Instances. This was done on the basis of the length of the bout of each of the different activities. Any behavioural bout occurring for less than a minute was considered as an Event Instance, whereas an Event State lasted a minute or longer.

This was done within the constraints of spotting an animal mostly when in an active state. Observations from waterholes were also made in different seasons. Three waterholes were identified, out of which one was a perennial spring, another was an artificial saucer and the third a check dam with water available till mid-summer. These waterholes were monitored three to five times every season, and observations of Four-horned Antelopes visiting them were recorded along with their detailed behaviour.

The main activity patterns that were not of the 'undisturbed' category were further classified into active and passive states. An active state was one in which the animal was on its feet, whereas a passive state was one in which an animal was either resting or ruminating. Active states were further classified into the following four major subclasses.

Foraging: When an individual was observed ingesting food, whether it was picking forage from the forest floor, browsing a shrub or nibbling herbs.

Walking: An activity where the animal was seen moving in a random or specific direction for over 10 m.

Threat response: Whenever the animal was in an alert position, sprinting or taking evasive action on seeing human or predators as a threat.

Other activities: All other activities were put together in this category as there were only a few recorded instances of some behaviour during our study period. While these could not be analysed statistically, they provided an insight into the natural history of a species whose behaviour was more or less unknown to science.

Any observation in which the animal was resting or ruminating was assigned to the passive mode. Activities were represented as the frequency of occurrence within an observation period. To avoid autocorrelation and to obtain independent behavioural bouts, animals were continuously observed within a timeframe, and only a change in an Event State or Event Instance was timed and recorded. Fig. 1 shows the percentage of time spent in the major classifications of behaviour in different time-slots.

Threat Response

For each sighting in the field, notes were taken about the escape mechanism employed by the Four-horned Antelope. It was observed that on different occasions, different strategies were employed to evade potential threats. Whenever the animal did not take any evasive action, quietly moved, trotted, walked with stiff legs or just quickly vanished into thick vegetation, the behaviour was classified as 'minimum distress' or 'Quiet'. Situations in which the animal took clumsy leaps with or without curiosity or resorted to short sprints were ranked as 'short evasive manoeuvres' or 'Clumsy & Short'. Whenever the animal reacted nervously to threats and took to sprinting, the behaviour was termed as 'hyper-evasion' or 'Hyper'.

Midden Mapping and Monitoring

Overall, 145 middens were identified and marked on the map after sampling six different areas. The spatial distribution of these middens in space was subjected to Poisson's test to investigate the level of clustering in the placement of these middens. Clustering would mean that the middens have an inductive effect and were possibly maintained by individuals, in order to demarcate home ranges or lure the other sex. It would also mean that their distribution across a habitat indicates visibility, accessibility and display rather than use of the respective habitat by the animal. The G-test for Poisson's (random) distribution was used to check clustering in space. We found that clustering was significant only in one area, namely Badi-saaj (chi square = 7.18; p = 0.00), which also had the highest number of direct sightings of the Four-horned Antelope (Table 3).

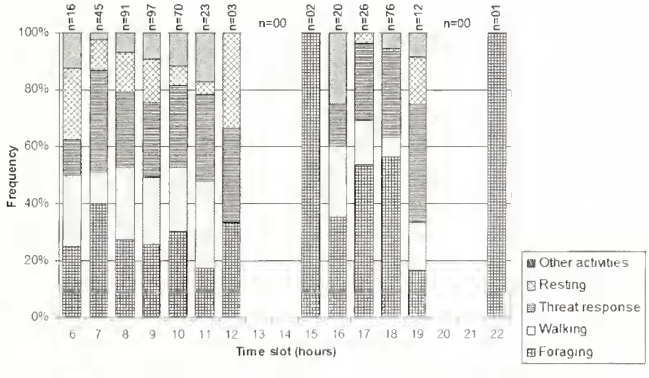

Fig. 1: Activity budgeting in terms of frequency of occurrence

DISCUSSION

Behavioural Classifications

(i) Foraging

The Four-horned Antelope is known to consume some grass in the early monsoon period and has specialised foraging preferences in other seasons (Rodgers and Panwar 1988). Preliminary data on foraging preferences of the Four-horned Antelope were obtained using the cafeteria experiment. As only one individual was available in captivity, the data do not have statistical robustness. Nevertheless, out of the 10 species of vegetation provided with equal access, 6 were consumed by the Four-horned Antelope in varying proportions (Table 2). None of the grasses were consumed, whereas *Zizyphus mauritiana*, *Acacia nilotica*, *Acacia leucophloea* and *Acacia catechu* were foraged in decreasing order of preference. Aonla and bamboo were consumed in small and insignificant proportions. Despite a lower preference in terms of the time spent in consumption, Babool was consumed before Ber, and in larger quantities. It was only after the stock of Babool was reduced that the animal moved towards Ber.

The captive Four-horned Antelope was alert and cautious when foraging. It would frequently raise its head and stop all other activities for a while before getting back to foraging. The level of alertness when foraging was much more than when it was ruminating or resting. The majority of the time between noon and evening was spent resting and sleeping in the shade. Occasional human disturbances also forced the animal to wake up and start ruminating after a certain period of caution had lapsed. Since a Babool tree inside the enclosure was in bloom, the Four-horned Antelope picked Babool flowers from the ground avidly. Interestingly, the animal preferred leaves to flowers when both were provided artificially, but consumed flowers whenever it found them on the ground. During the cafeteria experiment, the Four-horned Antelope showed no interest in ingesting any of the grass species other than nibbling some soft bamboo leaves on a couple of occasions.

Table 2: Food taken by the Four-horned Antelope during cafeteria experiment

Species	Time spent (%)
Aonla (*Emblica officinalis)*	3%
Babool *(Acacia nilotica)*	31%
Bamboo *(Dendrocalamus strictus)*	2%
Ber *(Zizyphus mauritiana)*	43%
Khair *(Acacia catechu)*	9%
Rencha *(Acacia leucophloea)*	11%

Foraging preferences of Four-horned Antelope are understood from limited direct observations (this study) and research with tamed animals under conditions that may or may not have reflected their native habitat preferences (Berwick 1974; Solanki and Naik 1998). The results of the other studies were similar to this one where the species showed a preference for nutritious plant parts, such as fruits, flowers, leaves over grass.

In the wild, the Four-horned Antelopes spent a significant amount of the observed time in foraging (Fig. 2). Jarman's (1974) hypothesis, re-established later statistically by Brashares *et al.* (2000), suggests that feeding selectivity is negatively correlated with body size and group size. Due to the volume: area ratio, smaller species require more energy per unit weight than do larger ones. Smaller antelopes have high metabolic requirements, but smaller stomachs in comparison to larger ruminants. This prevents them from taking large quantities of coarse forage that is high in fibre content and low in protein. As a result, smaller antelopes are more selective regarding their food. As with other antelopes of the same size (Jarman 1974), it is likely that since food that is high in protein content is scarce, the Four-horned Antelopes do not attain high abundances. The Four-horned Antelope seems to fit Jarman's hypothesis and tends to feed selectively. On almost all occasions when it was seen foraging, we examined the site after the animal had gone. The forage comprised mainly fruits, flowers, pods, or fresh leaves and petals, all high in nutritive quality. The animal was never seen grazing during the study period as was suggested by Rodgers and Panwar's (1988).

(ii) Resting

In a span of three years, we could observe Four-horned Antelopes resting only on 28 occasions. The difficulty in detecting animals resting in thick grass or undergrowth and their tendency to flush only as a last resort possibly resulted in such few observations.

Table 3: Patterns of middens within mapped areas

Site	Mean	Std. Dev	χ^2 (Poisson's)	P	Distribution
Pipartola	2.67	1.55	6.87	0.29	Poisson's
Badi Saaj	1.67	1.55	7.18	0.00	Clustered
Talgaon	1.16	0.83	2.52	0.45	Poisson's
Kwalan	1.67	1.55	1.58	0.67	Poisson's

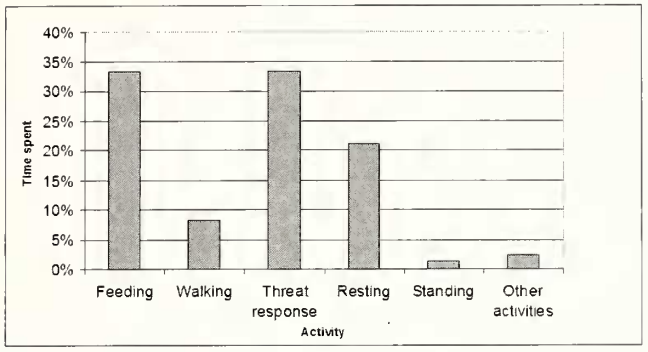

Fig. 2: Time spent in various activities as observed

Next to foraging and anti-predatory behaviour, the Four-horned Antelope displayed resting behaviour most frequently. The Four-horned Antelope prefers closed canopy thickets with dense undergrowth or grass cover for resting. Unlike the Chinkara, which invariably uses open terrain, forest clearings and forest roads for resting, the Four-horned Antelope was never found resting in the open. This observation is in contradiction with the conclusions arrived at by Bhaskaran (1999) who studied Four-horned Antelopes in Mudumalai and observed that they use forest roads for resting. We found that Four-horned Antelopes resting in the shade or in a thicket would usually flush only when the observer was less than 15 m away.

The Four-horned Antelope rests in the usual fashion of most ungulates. They fold their front legs, followed by hind legs, and bundle down, occupying the minimum possible space. Since the Four-horned Antelope usually rests in thickets with very low visibility, it is probably more dependent on its sense of hearing than its sight, when resting, to detect any disturbance.

Ruminating being an important aspect of the ecology of ungulates, they spend a significant amount of time performing this activity. The Four-horned Antelope usually ruminates while resting, but there were instances when an animal was seen chewing the cud even when standing. Out of the nine occasions when the Four-horned Antelope was observed ruminating, it was standing four times, whereas on the remaining occasions it was resting. Before ruminating, the Four-horned Antelopes spent a few minutes observing and assessing their ambience. Once the ambience was assessed, they twitched their stomachs with a slight jerk, which was followed by an apparent movement of the bolus through the oesophagus to the mouth.

(iii) Interaction

The Four-horned Antelope is a solitary animal. Since it is not usually seen in groups (69% solitary sightings, n = 824), there were few opportunities to directly observe interactions between individuals. Detailed behavioural notes could be taken on 41 individuals when they were in a group of two or more. Rapid scanning of the two or more individuals with a scan interval shorter than 1 minute was done, and overall, 341 behavioural bouts could be recorded. Sniffing, submission, trailing, mating and agonistic behaviour were the various events of interaction that could be observed on 40 occasions. On a few occasions, the Four-horned Antelope was seen interacting with other species as well, allowing inter-specific behaviour to be recorded.

a. Intra-specific interactions

a.1. Mating: A male and a female Four-horned Antelope were sighted at 0916 hrs on February 7, 2003. There had been brief showers during the previous few days. The pair moved briskly and briefly around a cluster of trees and bushes in the lower plateau of the Park, not more than 100 m from a steep cliff, in an open miscellaneous forest with medium undergrowth. On being observed, the Four-horned Antelope pair moved slightly away from the observers, and then the female started eating leaves of a low shrub. While the female was busy eating, the male approached her from behind and mounted her for about 2 seconds, to which female did not react at all and continued foraging. After dismounting, the male moved again and mounted her again, this time for a shorter duration, 1 second. Then the animals moved ahead and became attentive to passing villagers on a forest road, a few metres away. At 0919 hrs, the female ran away and was followed by the male till they both disappeared in the tall grass. The animals were rediscovered approximately 120 m from the first sighting spot, resting under a Tendu *Diospyros melanoxylon* tree at 1030 hrs. This time the animals did not react until the observers inadvertently flushed them out when they were just about 10 m away. The female and male ran swiftly in different directions instantaneously, but the male reunited with the female and joined her direction of movement after proceeding about 70 m. Later, attempts were made to relocate the pair in the area, but due to tall grass and bushy terrain, they could not be located.

a.2 Submission: A submissive posture can be defined as one where an individual shrinks its body, lowers the head and pulls the ears back. On April 16, 2003, two individuals were observed in a closed canopy area within a dense miscellaneous forest. The female started foraging after a short period of alertness, while the male remained alert and frozen. Circling around a cluster of bushes, the female approached the male and took a submissive posture, and the male sniffed her rear and started foraging. After a while, both the male and the female moved slowly while foraging selectively. After foraging for about half an hour, the male sat down in the

middle of medium height grass under an open-moderate canopy. The female sat down to rest after some time. It was evident that the pair was moving cohesively as we had a couple of relocations a few hundred meters away from the spot of the first sighting.

a.3 Kneeling submission: This is one of the most obvious and distinct interactions between two individuals, wherein an individual would approach another in a specific manner. Following a certain mode of communication, the other individual, not necessarily belonging to a particular sex or age group, would kneel down on its front legs with the rear of its body still up. The approaching individual would then come close and rub its neck with the kneeling antelope or examine it closely by sniffing it. This ritual usually lasted only a few seconds, after which both individuals would assume their normal postures. This behaviour was observed involving individuals of different sexes and age groups, once two fawns behaved in this fashion on being approached by an adult female. It seems that Four-horned Antelopes either communicate dominance and submission or use it to develop a bond with conspecifics with the help of such behaviour. This distinct behaviour was observed both in captive and wild Four-horned Antelopes. Shull (1958) also reported a kneeling 'courtship' between a male and a female Four-horned Antelope, which later mated.

a.4 Trailing: Following of an individual by another individual was categorized as 'trailing'. It was one of the most observed behavioural bouts involving any two individuals when seen together. Trailing was recorded on 46 occasions. It was mostly seen in fawns or juveniles following their mother, but occasionally it was observed in other age classes also, especially during the rutting season.

a.5 Female-fawn/juvenile interaction: The fawns seem to follow their mothers for almost a year or so. This was established on the basis of 41 direct sightings of fawns with females spread throughout the year. As determining the age was difficult in fawns, all individuals substantially smaller than adults (less than two thirds the size) were considered to be juveniles.

On five occasions a female was seen with a fawn and a juvenile. This proves that sometimes the juvenile moves with the mother even after she has given birth to another fawn. Whenever we saw a mother with a fawn or a juvenile, the latter followed the line of movement of the mother.

a.6 Nursing: On February 10, 2003, we saw a female suckling young ones. The two fawns were initially spotted by us. On the approach of their mother, they ran hastily towards her and started suckling, with one on either side of the mother and pushing persistently like the kids of a goat.

b. Inter-specific interactions

b.1 Four-horned Antelope and Langur: The Hanuman Langur *Semnopithecus entellus*, being mostly arboreal frugivores, usually forages on fruits and other vegetable matter in the trees. They are known to drop a mean of 4 kg of fresh vegetation per day (Newton 1989). It is also reported that for some species, such as the Aonla *Emblica officinalis*, fruit fall rates without Langur are as low as 1% of the fruit crop per day compared to when these trees are perched upon by Langurs. The relationship between the Chital and Langur is well-known and often referred to as a classical example of a commensal relationship. While some species like the Chital and Muntjac usually visit some fruiting tree species in small groups or pairs for short durations, with the presence of Langurs on the trees their group sizes increase and they spend longer durations foraging under these trees. This association is also known to have a key role in dispersal of plant species (Prasad *et al.* 2004). The Four-horned Antelope was seen associating with troops of Langurs for foraging on 20 occasions. It was seen foraging in association with Langurs under trees of Aonla, Bel *Aegle marmalos*, Bahera *Terminalia belarica*, Ghont *Ziziphus xylopara*, Kaitha *Feronia limonia* and Semal *Bombax ceiba*.

b.2 Four-horned Antelope and Chital: The Four-horned Antelope and Chital have an overlapping niche in dry deciduous forests (Berwick 1974, this study), where the former has a more widespread distribution than does the latter. The Chital, despite being a hardier and more generalist species than the Four-horned Antelope in terms of its foraging preferences, requires a greater extent of suitable habitat and larger amounts of food for its usually larger populations. Since the Chital lives in herds and the Four-horned Antelope is mostly solitary, the anti-predatory strategies of the two animals are different. Associations between two species with distinct anti-predatory behaviour and foraging preferences is rare but was recorded occasionally by us in Panna National Park. It was found that mostly at sites where Langurs were foraging on the top canopy, Chitals and Four-horned Antelopes were both seen benefiting from the items that were being dropped by the Langurs. Other than this, at some sites where closed forest stands were recently converted into open forests by uprooting of some trees, Four-horned Antelopes were occasionally seen foraging along with herds of Chital.

b.3 Four-horned Antelope, parasites and Treepie: Wild ungulates are hosts to ectoparasites and other insects (Krasnov *et al.* 2003; Miller *et al.* 2003; Wesonga *et al.* 2006). Some parasites play a major role in shaping the ecology and behaviour of the host species (Jog and Watve 2005). The seasonal distribution of some ungulates, including Four-horned Antelopes, changes in the monsoon, possibly due to

an explosion in the population of some parasites. It was observed that during the first two weeks of the monsoon, most ungulates possibly moved to the rockier areas of the study area. This was evident from the reduced encounter rate of Four-horned Antelopes in areas with a high incidence of parasites (Koustubh Sharma, unpubl. data).

The Treepie was the only bird which could be observed cleaning the ears of Four-horned Antelopes. It would perch on the root of the ear of a Four-horned Antelope, and the antelope would gently raise its head as if in acceptance of the act of cleaning. Treepies hang upside down when perching on the top of the ears of Four-horned Antelopes and pick ticks avidly while the animals stand almost still for getting the job done.

(iv) Threat response (anti-predatory behaviour)

An adult Four-horned Antelope weighs about 17-20 kg (Berwick 1974; Aniruddha Belsare pers. comm. 2007). Based on the relationship between body size, group size, feeding style and anti-predatory strategies of different antelopes of Africa, Jarman (1974) has proposed five social classes. Based on its size, weight and group size, the Four-horned Antelope seems to fit the description of Class A. According to Jarman's classification, antelopes from this category feed selectively on a wide range of plant species, use some plant parts only, remain in a restricted vegetation type and have a small home range. The feeding style of this class is further described as exclusive, as it feeds usually on single plant parts. These plant parts are removed wholly from the site. If animals classified as Class A feeders come to an area already fed upon by forerunners, they will have little to nibble upon as their forerunners would have either taken all of the acceptable items or would have at least consumed the more obvious or accessible ones. This is possibly one of the reasons why antelopes belonging to this class are solitary. As far as their anti-predatory behaviour is concerned, they depend largely on making themselves inconspicuous. In the presence of predators they freeze, lie down and freeze, or run to cover and freeze. Animals belonging to Class B also resort to similar tactics when it comes to dealing with a predator. They remain frozen until a predator is almost upon them and then take a short sprint to take themselves clear of the predator. Once at a safe distance, they hide again.

The Four-horned Antelope evades detection, and prefers hiding and freezing rather than fleeing instantaneously when it encounters a threat. It has a short flight distance, and only the crossing of this distance causes it to burst into a sprint.

a. Freezing (no movement and mock feeding): When threatened, the Four-horned Antelope usually resorts to the tactic of standing still without any movements. We classified this behavioural bout as 'freezing' or 'alert'. A record was also maintained of the duration of all particular freezing bouts (with resolution in minutes). The duration of frozen alert was observed to last from a few seconds to 17 minutes. The success of this freezing technique is evident from an observation in the field on December 12, 2003, when a Four-horned Antelope standing still in grass of medium height evaded detection by a Leopard walking just 6 m away.

b. Evasive action: Those actions where the animal moved significantly in response to threats were called evasive actions. As the bout interval for these events was generally short, all these events have been termed as Event Instances, and instead of duration, frequencies are used to analyse their occurrence. These patterns were further classified as various behavioural displays were observed when the animal took evasive action (Fig. 3).

c. Alarm calls (barking): The Four-horned Antelope sometimes make a shrieking alarm call. Its alarm calls are recurring, husky *pronk* calls repeated at regular intervals. It is rare to hear its alarm calls as its main anti-predatory strategy is to hide. These alarm calls are made only when the animal is faced with some special situations. Since the Four-horned Antelope is predominantly a solitary species, it is more likely that the alarm calls are used to warn the predator (Zahavi and Zahavi 1997; Reby *et al.* 1999; Bergstrom and Lachmann 2001) that it has been identified, rather than to warn conspecifics about the presence of a predator (Hauser 1996; Blumstein 2001).

The alarm calls are made at intervals of 5 to 10 seconds when the animal is standing, and at a much greater frequency of 0.5 seconds, when sprinting. These calls are diagnostically different from those of Chital and Nilgai as they are shriller than those of a Nilgai and huskier than those of the Chital Fig. 4 shows the spectrogram of the alarm calls made by a male which had sensed the presence of some predator and made alarm calls continuously for over 5 minutes.

(v) Communication

Olfaction plays a prominent role in the interactions of many ungulates with their environment. It is widely accepted that most forest-dwelling antelopes (e.g., Duikers and Kirk's Dikdik) and deer (e.g., Chevrotains and Muntjacs) rely primarily on their sense of smell for orientation and communication, as well as in the social context (Leuthold 1977; Geist 1987).

The modes of communication between Four-horned Antelopes are largely unknown apart from the alarm calls that are made in response to threats. The following modes of intra-specific communication were considered, based on our field observations.

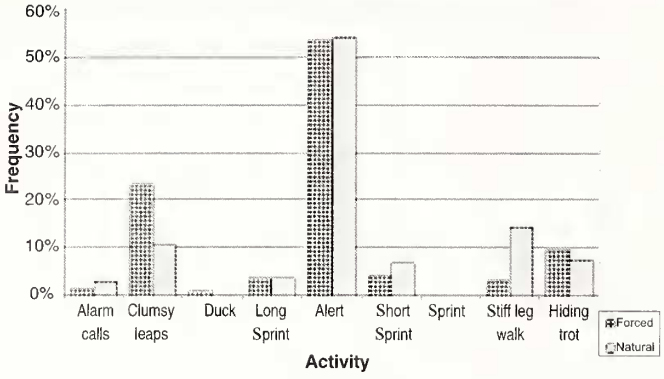

Fig. 3: Frequency of occurrence of events of anti-predatory behaviour (natural stimuli, n = 133; forced stimuli, n = 219)

a. Preorbital gland marking: A captive adult male was first observed in Van Vihar National Park of Bhopal marking the sharp tips of thorns and the fence wire with its preorbital glands. Only the adult male displayed this behaviour, whereas the younger male displayed no such activity. On many occasions in the wild, the Four-horned Antelope was seen marking with its preorbitals. Marking consisted of sniffing the twig or thorn and piercing it in its head sideways through the preorbital glands. This marking leaves a colourless liquid on the substrate. This liquid crystallises into a white solid film on the substrate within a few seconds of deposition. In the field, adult individuals, both male and female, were observed marking on twigs, thorns and grass tips with their preorbital glands. This method is widely used by many other territorial antelopes and deer (Brashares and Arcese 1999; Burger 2005). The habit of marking with preorbitals was displayed by both males and females, but was never observed in fawns.

b. Urination and defecation: Urination and defecation are perhaps the most generalised forms of scent marking. Biological waste also plays an important part in establishing the role of ungulates in stimulation of nitrogen cycling and retention, and modification of ecosystems (Hobbs 1996; Frank *et al.* 2000). It was observed that Four-horned Antelopes defecated regularly on middens. A couple of direct observations of defecation on such middens by males, females and even fawns prove that middens are also used as communication points. Mapping of middens and their periodical regular monitoring was done in order to understand the parameters influencing site selection and frequency of defecation on middens (Sharma 2006).

c. Calling: On two occasions, a Four-horned Antelope was heard making calls which were not very different from its diagnostic alarm calls, but with a lower amplitude. On February 6, 2004, a pair was seen courting. The male walked towards and away from the female while making distinct *cough* calls that were milder and more persistent than the alarm calls, and in a less strained posture (ears and feet movement relatively relaxed compared with the typical alert posture). On another occasion, where tiny fawns were observed hidden amidst thick undergrowth, the female made soft calls. After this call, the fawns proceeded in the direction from where she had called and vanished into thick vegetation.

It was also observed that adult female Four-horned antelope uses shrill calls that sound more like alarm calls to warn or communicate with its young ones. On one occasion a female approached a waterhole with her juvenile fawn. When the juvenile and the female were separated by about 30 m, the female got disturbed about some potential threat and burst into a long sprint, continuously making alarm calls at short intervals. The fawn, which was about a year old, followed her immediately after hearing the calls, without waiting to look around for the threat.

Midden Mapping and Monitoring

The way faeces are distributed in space is often indicative of an animal's social status. Voidance in one animal often induces the same in others (allelomimetic behaviour), particularly between mother and young, and even different species. To investigate midden maintenance behaviour, each of the identified middens was given a unique midden code for further reference.

Regular monitoring and a few direct observations revealed that the middens were used by both sexes and that

Fig. 4: Spectrogram of alarm calls made by the Four-horned Antelope

even the fawns accompanying their mother defecated on them. No determined and directional movement was observed specifically towards the middens, but apart from a few exceptional instances, faecal pellets were essentially released whenever a Four-horned Antelope came across a midden.

Identification of pellets was difficult at times when a Nilgai calf defecated on a midden as its pellets look similar to those of a Four-horned Antelope. Likewise, pellets of the young ones of Chinkara and Four-horned Antelope were also confusingly similar. To resolve this problem, based on direct observations of the three species defecating at middens on different occasions, we assume that a fawn will defecate on a midden only when accompanying its mother. This would mean that two fresh defecation heaps (one with small pellets and the other with bigger pellets) would be found on a midden whenever a young one had defecated on it. While there could surely be some deviations from this assumed behaviour, we never came across any direct observation contradicting this assumption.

The only area where clusters were observed was Badi Saaj. However, the reasons for such a clustering in this area are unknown, but could be probably credited to the high density of the population in this region (Sharma 2006).

CONCLUSION

The Four-horned Antelope is elusive and difficult to be observed in most areas of its distribution. Other than a few observations, there are few studies on its behaviour. Although the data presented in this paper lacks statistical robustness due to inadequate data, it provides useful information about two critical aspects of an ungulate's natural history — its antipredatory strategies and its foraging preferences. Study of the phenology of the flora of Panna National Park, which is a dry deciduous forest, reveals that there is a continuous availability of palatable fruits, flowers or pods throughout the year in areas with high density of Four-horned Antelope (Sharma *et al.* 2007). This is an important factor for a species which needs to forage on high protein diet. Being a cryptic animal preferring to hide and freeze rather than sprint, Four-horned Antelope needs good undergrowth cover which is just right to hide, and at the same time helps it keep an eye on the predator. Areas that have extremely thick understories are usually avoided, and so are areas with no or minimal undergrowth.

ACKNOWLEDGEMENTS

The work presented in this paper was supported by the Department of Science and Technology (DST) to the Bombay Natural History Society for its project on the ecology and distribution of Four-horned Antelope, and we are grateful to both the organisations. We would like to also thank the State Forest Department of Madhya Pradesh for providing necessary permits to conduct this study in Panna National Park. We are grateful to Dr. George Schaller, Dr. Y. Jhala, Mr. Qamar Qureshi, Mr. Faiyaz Khudsar and Mr. B.M.S. Rathore for their useful comments and support at different occasions during the study. We are deeply grateful to the field assistants for their dedicated assistance through the study. We are highly thankful to Mr. Kumaran for his useful editorial assistance.

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